Antiproton Source & the Proton Driver

Paul Derwent

Proton Driver Workshop

6 Oct 2004

Initial Run II Goals

* Goals Initial Phase
  - -> Peak Accumulation Rate
    - 20 e10/hr (current best 13e10/hr)
  - -> Accumulate for 15-20 hours
  - -> Final Pbar Parameters: **Stacked in Accumulator!**
    - ~200e10 pbars
    - Transverse emittance ~10π mm mr (95% normalized)
    - Longitudinal emittance ~40ev-Sec

* Inputs
  - -> 5e12 Protons on Target (current best 7e12 with slip stacking)
  - -> $1x10^{8}$ Pbars into Debuncher every 1.5 seconds (current best $8x10^{7}$ every 2 seconds)
    - ±2% momentum spread
    - <0.8 nsec bunch length (defined by bunch length on target)

Run II Upgrade Goals

* Goals Upgrade Phase
  - -> Accumulation Rate
    - Peak: 45 e10/hr
    - Average: 40e10/hr
  - -> Accumulate for 15 hours
  - -> Final Pbar Parameters: **Stacked in Recycler!**
    - ~600e10 pbars
    - Transverse emittance ~10π mm mr (95% normalized)
    - Longitudinal emittance ~54ev-Sec

* Inputs
  - -> 8e12 Protons on Target
  - -> $3x10^8$ Pbars into Debuncher every 2.0 seconds
    - ±2% momentum spread
    - <1.5 nsec bunch length (defined by bunch length on target)
    - Lens and aperture upgrades to increase flux/proton to Debuncher

Strategy

* Present Operations

-> Accumulator: final repository for pbars

-> Stochastic Cooling:

- Cooling time ~ Number of particles
- Limits
  - cycle time (Debuncher cooling)
  - stack size ~ 300e10
  - stacking rate falls off with stack size (gain and cycle time)

-> Transfer to Tevatron ~ 1/day

* Future Operations

-> Recycler : final repository for antiprotons

-> Electron Cooling:

- Cooling Time ~ Independent Number of particles
  - Stack Size: ~600×10^{10}
  - Stacking Rate: ~ Independent of Stack size

-> Accumulator:

- Optimized for flux, not density
- Smaller Stack size: ~30×10^{10}
- Still limited by cooling in Debuncher and stacktail

-> Frequent (2/hour) transfers between Accumulator and Recycler

-> Transfer to Tevatron ~1/day

Accumulation Process

* Diffuse, low intensity pbar beam from target
  -> Every 2 seconds
  ->
* Combination of stochastic and electron cooling
  -> Combine many pulses
  -> Cool transverse and longitudinal phase space
  ->
* Cold, high intensity pbar beam for the Tevatron
*

Density Variable: Number per phase space volume

$$\frac{\rho_{6D}}{(\pi \,\mathrm{mm\ mr})^2 \mathrm{eVsec}} = \frac{\mathrm{N}_{particles}}{\varepsilon_H \varepsilon_V \varepsilon_L}$$

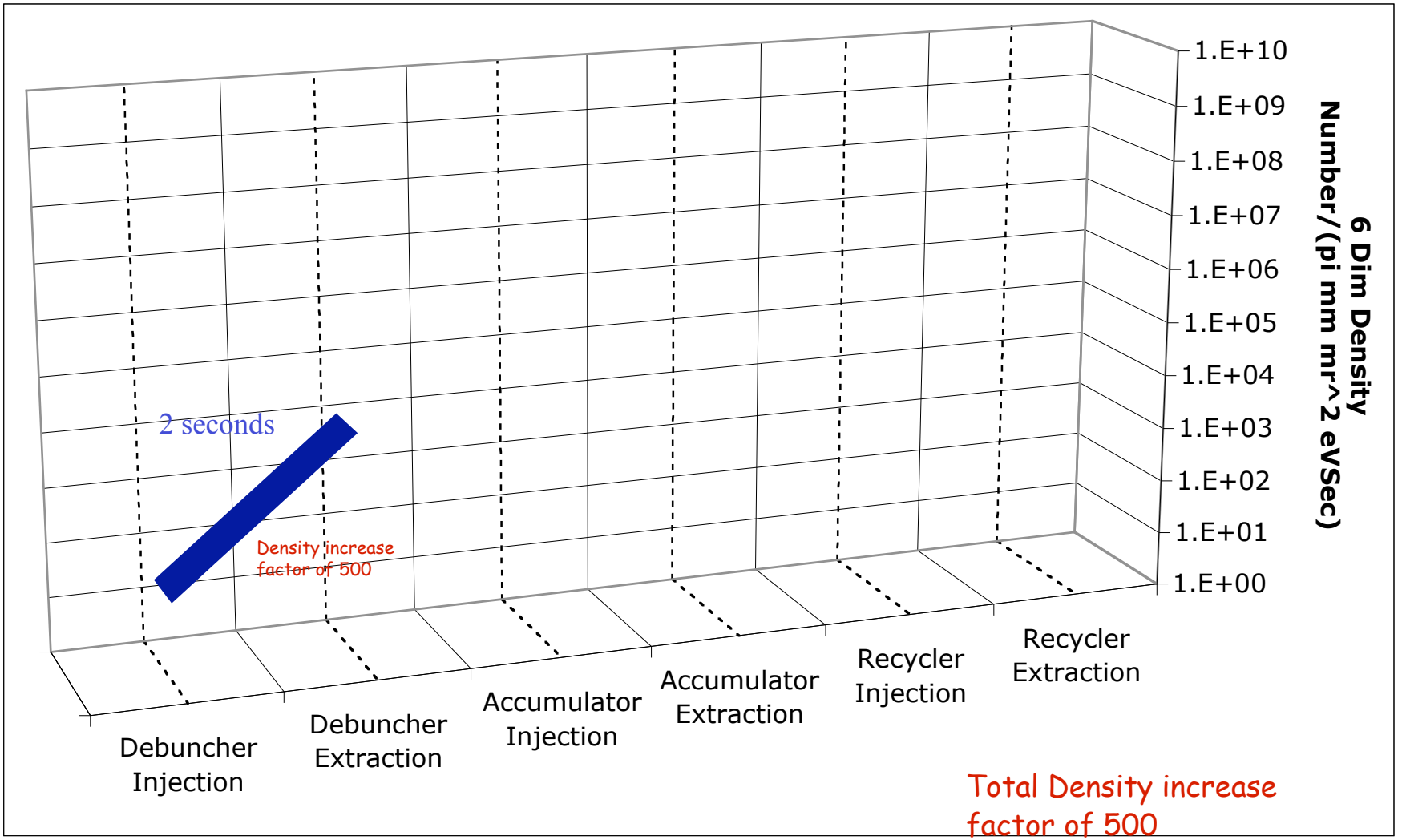
Debuncher Cooling

* Debuncher: every 2 seconds collect beam from AP2, cool, and transfer to Accumulator
  - -> RF Bunch Rotation
    - Exchange momentum spread for time spread
    - $\rho_{6D} \sim 29$
  - -> Stochastic Cooling
    - Liquid He temperature pickups
    - 4-8 GHz in 4 separate bands
    -
    - Momentum: 10x compression in 2 Seconds
      - 95% width: 6 MeV/c
    - Transverse: 7x compression in 2 seconds
      - 45 π mm mr
      -
  - -> Extraction to Accumulator
    - $\rho_{6D} \sim 13{,}700$

More pbars, slower cooling (1/N) longer cycles

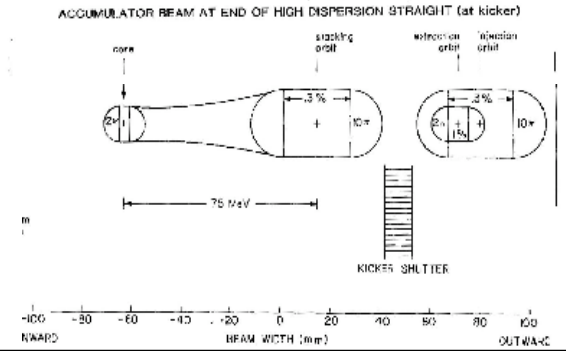
would need improvements here!

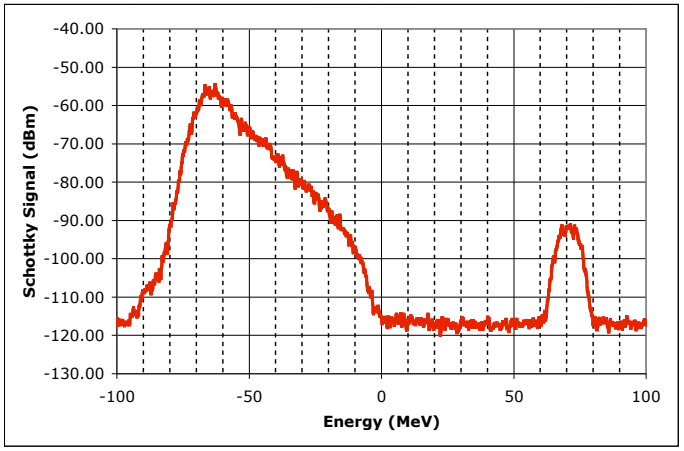
Phase Space Density -- Debuncher



Accumulator Cooling

* Accumulator Stacking
  - -> Process
    - Every 2 seconds
      - Beam is injected
      - ρ_{6D} ~ 13,000
      - Beam is bunched with RF
      - Moved with RF to the Stacking orbit
      - Debunched on Stacking orbit
    - Stacktail pushes and compresses beam to the Core
    - Transverse Core cooling system cools the beam transversely in the stacktail and the core
  - -> Accumulate ~ 30 minutes, transfer to Recycler
    - ρ_{6D} ~ 237,000,000

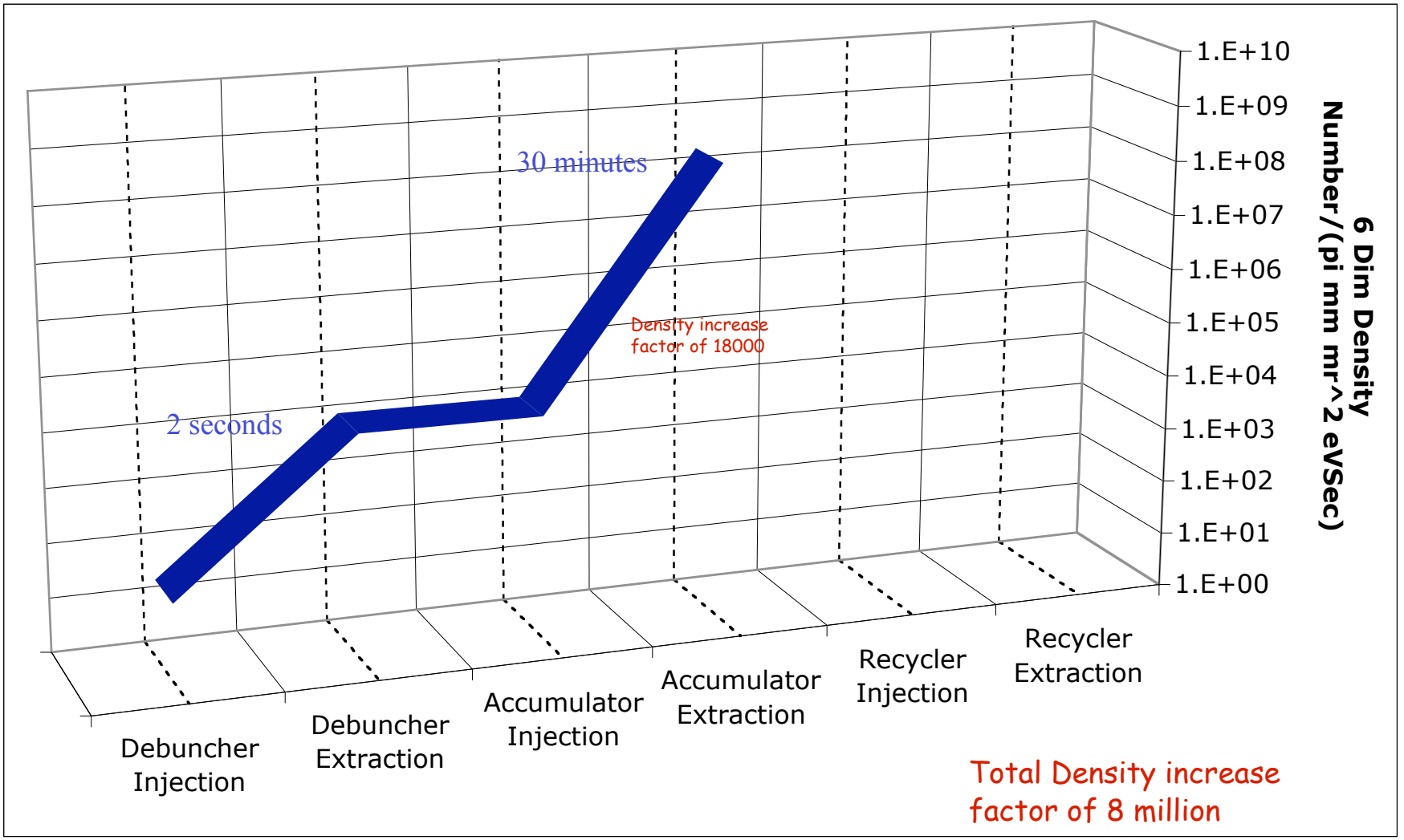




More Pbars,
1/N cooling time

Instabilities,
more frequent transfers

Phase Space Density -- Accumulator



Recycler

* Stochastic Cooling:
  -> Every $^1/_2$ hour
  - ρ_{6D} ~ 100,000,000
  - ~22×10^{10} pbars in ~15 eV-sec and 12 π mm mr
  - Transverse stochastic cooling of injected beam
    - to cool within reach of electron cooling
      » fits within the e-beam
    - kept separate from main stack by barrier buckets

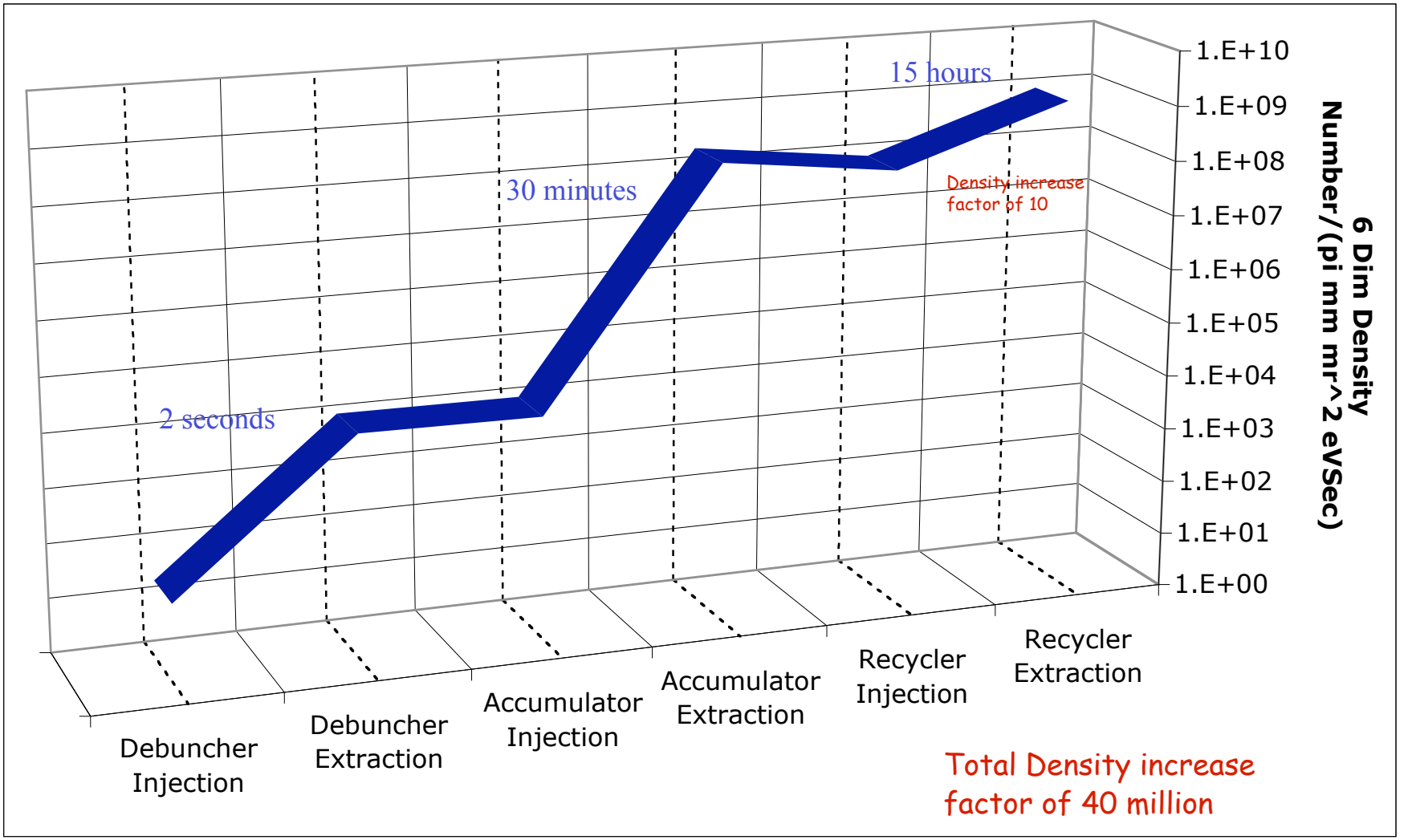
More pbars
More Frequent transfers
1/N cooling time

* Electron Cooling
  -> Process: Every $^1/_2$ hour
  -> Injected batch merged into the stack with RF barrier manipulations
  -> The Recycler stack
    - Is cooled mainly with electron cooling in all 3 planes
    - Weak transverse stochastic cooling for high amplitude particles
  -> After 15 hours:
    - ρ_{6D} ~ 1,080,000,000

More pbars
More Frequent transfers

Instabilities
Cooling rates
More e-beam current?

Phase Space Density -- Recycler



Stacking Process

* Through stochastic and electron cooling
  - -> Diffuse, low intensity beam → cold high intensity beam
  - -> ρ_{6D} increased by factor of 40 million
  - -> Limited by
    - input flux into debuncher → aperture upgrades
    - cooling performance
      - Debuncher
      - Accumulator
      - Recycler
      -

Higher intensity
Slower: 1/N cooling

More Frequent Acc→Rec Transfers

* Achieved by:
  - -> Optimizing Accumulator for flux
  - -> Integrating Recycler into operations
  - -> Utilizing Electron Cooling at 8 GeV
    - Size ~ 600×10^{10} pbars
    - Transverse emittance ~ 10π mm mr
    - Longitudinal emittance ~54 eV-sec

Need significant improvements in all cooling systems

Stochastic in Deb, Acc, Rec

Electron in Recycler

If everything worked perfectly...

* With proton driver, double beam on target (1.5 - 2 e13)
  - -> Collect all beam of target
    - Beam sweeping to keep target from disintegrating
  - -> Transport to Debuncher
  - -> Improve Debuncher Cooling performance (momentum and transverse) by ~factor 2
    - double beam intensity, halves cooling rate
    - double performance, meet initial specifications
    - Need another cooling orbit -- in Acc? new Ring?
  - -> Push Accumulator Stacktail to (beyond?) stability limits, transfer every 15 minutes
  - -> Improve Recycler cooling performance (transverse) by ~ factor 2
  - -> Improve Electron cooling rates by factor ~2
    - Doubling Pelletron current to 1 A
  - -> Push Recycler stability limits at expense of longitudinal emittance (roughly double)

  - -> 1e13 in 60eV-sec in 15 hour time period?
    - with significant upgrades over Run II Upgrade program